

THE TOBACCO RANGE FRACTURE ZONE, BELIZE, C.A.:

A UNIQUE SYSTEM OF SLUMPED MANGROVE PEAT

BY

Mark M. Littler¹, Diane S. Littler¹, Ian G. Macintyre², Barrett L. Brooks¹,
Phillip R. Taylor³, and Brian E. Lapointe⁴

ABSTRACT

During February 1986, a 0.5 km-wide by 2.0 km-long region of spectacular bottom topography was discovered off the west coast of the northernmost island of the Tobacco Range mangrove group, Belize. This unusual marine landscape consisted of vertical submarine peat exposures, tilted slumping blocks of fossil peat, and long narrow fractures. The upper edges of the exposed vertical walls were composed of a 10 to 20 cm-thick veneer of a living *Thalassia testudinum* community atop a 1 to 7 m-thick consolidated layer of fossil mangrove peat. This seagrass-dominated peat surface sloped westward to its point of lowest relief (<1.0 m, 500 m offshore) and contained poorly sorted sandy gravels and gravelly carbonate sands (mostly mollusc and foraminiferan fragments) on the unfractured surfaces and muddy calcareous peat sediments within the fracture depressions. The widths of the fractures varied from narrow fissures (< 0.1 m-wide) to upwards of 30 m across. Fractures nearest the island tended to be at right angles to the shoreline, dendritic or digital, and less weathered than those farther seaward. Fractures toward the northeast and southwest ends of the system retained vertical or undercut walls up to 7-m thick along their entire perimeters, whereas central fractures tended to have collapsed outer walls. Most of the slumped blocks contained sparse *T. testudinum* beds

¹ Department of Botany, National Museum of Natural History, MRC#166, Smithsonian Institution, Washington, D.C. 20560, U.S.A.

² Department of Paleobiology, National Museum of Natural History, MRC#125, Smithsonian Institution, Washington, D.C. 20560, U.S.A.

³ Division of Ocean Sciences, National Science Foundation, 4201 Wilson Blvd., Arlington, VA 22230, U.S.A.

⁴ Harbor Branch Oceanographic Institution, Route 3, P.O. Box 297A, Big Pine Key, FL 33043, U.S.A.

identifying their upper surfaces and had been tilted at chaotic angles ranging from horizontal to 35°. Multiple levels, platforms, and undercuts are conspicuous along most of the vertical walls revealing the preservation of a bedded zonal pattern in the peat. The majority of the peat is coarse-fibered material of mangrove origin, with partially decomposed fine-fibered deposits in the lower strata.

The Tobacco Range fracture zone has provided some unusual habitats for marine organisms. In general, the overall biota was sparse, consisting of the typical members of the *T. testudinum* community plus certain unique elements. The unusual elements appear to be in response to (1) new spatial heterogeneity adding increased surface area and shelter, (2) diverse sedimentary substrates utilized by psammobiotic forms, and (3) a trapping effect that concentrates large mobile gastropods. This last phenomenon has resulted in "interior halos", since the physical bioturbation by these large animals apparently has eliminated rooted plant life and other sessile organisms along the perimeters of the sedimentary depressions at the bases of the vertical peat walls.

The peat slurry between the slumped blocks of coarse-fibered peat at the innermost limits of slumping, the undercut peat exposures at the lowest depositional levels, the decomposed sections of fine-fibered peat found in cores adjacent to slumping, the presence of escaping stained humic waters, and the interconnected dendritic slump patterns all suggest that fracturing and slumping may be related to aerobic decomposition and erosion following hydrostatic intrusion of the underlying fine-fibered peat. The subdued relief of the peat blocks in the broad depressions at the outer limits of slumping indicates that collapsing of submerged peat has been taking place for centuries and possibly millennia. The isolated fracture areas eventually become interconnected by additional dendritic branches, which continue to slump to form broader slump depressions.

INTRODUCTION

On 18 February 1986, the research-team took advantage of unusually calm waters to explore bottom habitats to the north of the Smithsonian Institution's field station on Carrie Bow Cay (Fig. 1). We cruised an inflatable boat at 10 knots while observing the bottom topography to depths of 5-10 m. However, we were unprepared for the sharp 3-dimensional fractured relief that suddenly appeared in the otherwise monotonous beds of *Thalassia testudinum* König at the Tobacco Range mangrove group (Fig. 1). The following day an aerial survey was flown with oblique photography (e.g., see Frontispiece, this volume) used to document the overall Tobacco Range geomorphology and the extent of the fractures. These photographs were compiled to produce the map in Figure 2, which revealed a tendency toward a digital pattern of slumping with longer and narrower depressions extending shoreward, but not quite reaching the intertidal zone. There were also several isolat-

ed slump depressions near the coastline (Figs. 2 and 3). Reconnaissance by snorkling revealed an extensive 2.0 km-long by 0.5 km-wide region of spectacular bottom topography comprised of vertical submarine peat exposures, tilted slumping blocks of fossil peat, and long narrow fractures extending along the north coast of the northernmost island. Herein we provide an overview description and photographs of this unusual marine landscape which has stimulated more detailed biological and geological studies.

Geomorphology

Adjacent to the shoreline, the peat was pockmarked with small eroded depressions (up to 20 cm wide) caused by wave action and the predominant cover was the ruffled form of *Lobophora variegata* (Lamouroux) Womersley (see Littler *et al.* 1989, page 114). This approximately 10-m wide shallow zone graded into a *Thalassia testudinum* community that continued to the lagoon floor beyond the fracture zone. The peat between the shoreline and the fracture zone had numerous 1-m deep depressions (up to 5-m wide), gouged by trapped logs and debris, containing carbonate and peat sediments (see Fig. 13 of Macintyre *et al.*, 1995 this volume). Relatively few of the fractured peat blocks or walls showed evidence of erosion by water movement in their shoreward perimeters (Fig. 4), i.e., most have flat walls and angular corners. The upper edges of the exposed vertical walls were composed of a 10 to 20 cm-thick veneer of a living *Thalassia testudinum* community (Fig. 5) atop a 1 to 7m-thick consolidated layer of fossil mangrove peat. This seagrass dominated peat surface sloped westward to its thinnest point (< 1.0 m, 0.3 to 0.5 km offshore) and contained scattered pockets of poorly sorted organic debris and skeletal carbonate sediments. It is this gradually sloping peat seafloor that has been broken up to form the unique bottom topography of the area.

The widths of the fractures generally varied from <0.1 m-wide fissures (Fig. 6) to basins of 30 m across (Fig. 2). The fractures consisted of vertical walls, occasionally undercut, that dropped from the shallow 1-4 m level of the *Thalassia testudinum* bed to a depth of 2-10 m (Fig. 7). Fracture walls near the island (southeastward) tended to be at right angles to the shoreline, digital or dendritic, and less weathered (younger) than those farthest seaward. The majority of new cracks (Fig. 6) occurred on the shoreward margin of the fracture zone. Toward the northwest, several of the weathered central fractures graded deeper into smooth rounded peat hummocks on a *T. testudinum*-covered muddy-sand lagoonal bottom at about 300-500 m offshore (Fig. 2), implying that the central seaward portion of the system began fracturing earlier. Interestingly, fractures toward the northeast and particularly toward the southwest ends of the system (Fig. 2) tended to retain vertical or undercut walls along their entire perimeters.

Within the fractures, on the bottom or partially sunken into soft mud sediments, are large slumped fragments of the consolidated mangrove peat, most of which are angular and block-like in shape (Fig. 8). These blocks are in various stages of splitting off from the *Thalassia testudinum* flats at the edges, followed by vertical to tilted slumping and sinking into the slurry of partially decomposed peat muds at the bottom of the fractures (Fig. 9). This process is ongoing, as documented by the photograph of one large block falling away from the perimeter of a fracture (Fig. 10). Most of the slumped blocks still contain sparse *T. testudinum* beds that identify their upper surfaces, which have been tilted at angles ranging from horizontal to 35° (Fig. 11A). Some of the blocks that have sunken into the fracture depressions exhibit the classical backward tilting associated with slump features (Fig. 11B, Thornbury, 1954); however, other blocks form a chaotic jumble (Fig. 12) with no consistent orientation. Multiple levels, platforms, and undercuts are apparent along most of the vertical edges of the peat deposits revealing the preservation of a bedded structure in the peat (Figs. 13 and 14). This presents a stratified pattern of beds particularly evident on the more freshly fractured surfaces. Stained humic waters often escape from the interface between the bottom sediments and the basal strata of fine-fibered peat, greatly diminishing water clarity, and implicating deep hydrostatic flows. Most of the peat consists of preserved coarse-fibered material of mangrove origin with a well-developed *Thalassia* root system in the upper sections. There are occasional intact mangrove tree trunks and root systems within the upper strata, mostly <2 m deep, that show excellent preservation.

Sedimentology

During March 1987, a series of surface-sediment samples were collected at ~ 60 m intervals from two 300 m-long transects across the central region of the fracture zone. These transects, one extending from the northwestern end of the core study transect (Macintyre et al., 1995, this volume) and the other 100 m to the southwest, began in the near-shore unfractured peat and extended across both relatively fresh and older slump areas, to the level *Thalassia*-covered lagoonal bottom west of the fracture zone.

The sediment samples were treated with 5% sodium hypochlorite to remove dissolvable organic matter and separated into three basic size fractions by wet sieving: gravel (>2 mm), sand (2 mm to 63 μm), and silt (63 μm to 4 μm), whereas clays (<4 μm) were separated by settling and decantation. The textual classification of Folk (1961), relating the percentage gravel to the ratio of sand to mud (including both the silt and clay fractions), was used to describe the samples (Fig. 15) recognizing the inherent difficulty of carrying out size analyses on sediments that

include a mixture of both carbonate grains and peat debris. In addition, the sand and gravel fractions were studied microscopically to determine the origins of the major constituents (Fig. 15).

The gravel and sand-sized carbonate fractions did not vary substantially between the two transects. Molluscs and benthic foraminifera (predominantly peneroplids) were the dominant contributors with varying minor amounts of *Halimeda* segments and echinoid fragments. The better sorted sandy gravels and gravelly carbonate sands of the unfractured peat surfaces gave way to muddy calcareous peat sediments in the fractured and slumped areas (Fig. 15), which included more calcareous components with increasing distance from shore (visible in Frontispiece, this volume). Finally, somewhat muddy, gravelly carbonate sediments (with only traces of peat) occurred in the 6 m-deep *Thalassia* beds beyond the fracture zone.

Biology

Observations of the general biota were made from maneuverable tow boards (Tsuda and Abbott, 1985) along transects on 20-21 February 1986. The biota within the fractures was sparse and, with few exceptions, relatively uniform from fracture to fracture. The plant communities and composition are detailed in Littler et al. (1995, this volume) and were dominated by the *Thalassia testudinum* community on the upper surfaces of both slumped and unslumped peat. The brown alga *Lobophora variegata* was abundant on the vertical walls (Fig. 16) along with patches of the green algae *Caulerpa* spp., *Anadyomene stellata* (Wulfen) C. Agardh, and the seagrass *Halophila decipiens* Ostenfeld. The soft mud and sand bottoms of fractures were dominated by patchily distributed populations of siphonaceous algae having root-like rhizoidal systems [e.g., rhizophytes such as *Halimeda incrassata* (Ellis) Lamouroux, *Halimeda monile* (Ellis & Solander) Lamouroux, *Udotea cyathiformis* Decaisne, *Penicillus capitatus* Lamarck, and *Rhypocephalus phoenix* (Ellis & Solander) Kützing (Fig. 17) along with patches of the seagrass *Halophila decipiens* (Fig. 18)]. Abundant drift blades of *T. testudinum* contributed massive quantities of organic debris to the system (Fig. 19).

The most conspicuous sessile animal species were two sponges, the yellow semi-encrusting form *Mycale laevis* (Carter) (Fig. 20) reaching sizes exceeding 0.25 m² and the burgundy vasiform species *Mycale laxissima* Duch. & Mich. (Fig. 21) reaching 0.1 m² in diameter. Also common were the pink sponge *Monanchora unguifera* (Laubenfels), the white sponge *Leucosolenia* sp., and the black ball sponge *Ircinia felix* (Duch. & Mich.). On the fracture walls, the large black tunicate *Ascidia nigra* (Savigny) was also conspicuous, while colonies of the orange tunicate *Ecteinascidia turbinata* Herdman (Fig. 22) were common but otherwise rare on nearby mangrove

systems (i.e., north of the Blue Ground Range, Fig. 1). The giant anemone *Condylactis gigantea* (Weinland) was frequent on sunken peat blocks.

Of the mobile fauna, the jellyfish *Casiopea xamachana* Bigelow was abundant on the muddy sedimentary surfaces (Fig. 23). Nurse sharks (*Ginglymostoma cirratum* Bonnaterre) were common and the southern stingray (*Dasyatis americana* Hildenbrand and Schroeder) was frequently observed buried in the soft sediments (Fig. 24A) where it caused considerable bioturbation (Fig. 24B).

One of the fascinating features of the fracture zone was that large mobile gastropods had fallen into the fractures and become trapped because they could not ascend the vertical peat walls (Fig. 25A). These included three species of large helmet shells, *Cassis tuberosa* L., *Cassis flammea* L., and *Cassis madagascariensis* Clench as well as the queen conch *Strombus gigas* L. and the milk conch *Strombus costatus* Gmelin. These large gastropods apparently traversed the bottom sediments until encountering a vertical wall which they then paralleled until presumably starving to death (Fig. 25B). In 1986, there were dozens of examples, mostly dead but some living, each at the end of its grooved trail. This phenomenon has resulted in what we have termed "interior halos", since the physical bioturbation by these large animals apparently eliminated rooted plant life and other sessile organisms (Fig. 25A & B) along the perimeters of the depressions at the bases of the peat walls.

The spatial heterogeneity created by the slumped peat blocks (e.g., crevices, undercut ledges, Figs. 8, 11, 12, and 14) provided refuge habitats for various fishes and crustaceans that were not present in normal seagrass beds. Fishes responding to the rugosity with augmented populations were cuberra snapper (*Lutjanus cyanopterus* Cuvier and Valenciennes), grey snapper (*Lutjanus griseus* Linnaeus), yellowtail snapper (*Ocyurus chrysurus* Bloch), blue striped grunt (*Haemulon sciurus* Shaw), blue tang (*Acanthurus coeruleus* Bloch and Schneider), blue head wrasse (*Thalassoma bifasciatum* Bloch), and stoplight parrotfish (*Sparisoma viride* Bonnaterre). Other fishes utilizing the sunken topographic relief of the fractures in numbers exceeding those of the surrounding seagrass beds were yellow goatfish (*Mulloides martinicus* Cuvier and Valenciennes) and, as mentioned, southern stingrays and nurse sharks.

The Caribbean spiny lobster *Panulirus argus* (Latreille) was common in peat crevices of the southwestern fractures, while the Caribbean king crab *Mithrax spinosissimus* was common on vertical faces in the shoreward shallow portions of the fractures.

Heart urchins [*Meoma ventricosa* (Lam.)] were abundant along with the crown conch *Melongena melongena* L. in the fractures (particularly the more-westward

predominantly carbonate-rich sediments). Uniquely, the sea urchin *Astropyga magnifica* Clark (Fig. 26), which occurs typically only in very deep oceanic waters, was present in two of the southwesternmost fractures, representing the only known collection record for this species from Belize (D. Pawson, personal communication, 1995). The long-spined sea urchin *Diadema antillarum* Philippi (Fig. 27) was also common.

DISCUSSION

We have observed submerged peat exposed on the seafloor margins and interior channels of most mangrove islands and there are particularly good examples to the southwest at nearby Twin Cays. However, to our knowledge there are no reported sites of fracturing and slumping, comparable to that occurring at Tobacco Range, in the Central Barrier Reef Province of Belize. There is, however, one area adjacent to the mangrove shoreline north of Crickozeen Creek, on the west coast of the Tunneffe Islands, Northern Belize Barrier Reef Province, where similar fracturing and slumping may have occurred (Stoddart, 1963). This crescent-shaped slump area was about 10 m wide and approximately 200 m long with "subsidiary smaller cracks both to the south and seaward". Unfortunately, the area was not studied in detail, so that it is not known whether the slumping is associated with peat deposits. Stoddart suggested that this slumping was caused by "extreme wave conditions" (p. 87) that occurred during the impact of Hurricane Haiti, which had just passed over the area four months prior to his observations.

The relatively larger slump depressions toward the center of the array off Tobacco Range (Figs. 2 and 3) are more collapsed and weathered at their outer seaward margins suggesting that this region of the system fractured earlier than some of the more active shoreward (eastward), northern, and southern portions.

The Tobacco Range fracture zone has provided some atypical habitats for marine organisms. In general, the overall biota was sparse, consisting of the constituents of the typical *Thalassia* community plus certain unusual or even unique elements. The unusual elements seem to be in response to: (1) new spatial heterogeneity adding shelter and increased surface area, (2) soft substrates utilized by sediment dwellers, and (3) a trapping effect that concentrates large mobile gastropods creating "interior halos".

The overriding questions concerning the Tobacco Range fracture zone are: What initiated the fracturing and slumping?; How long has this process occurred?; and What controls the pattern of slumping? Considering the possible causes, the five most realistic hypotheses are:

- (1) Subsurface aerobic decomposition of fossil peat in the presence of oxygenated ground waters.
- (2) Hydrostatically-induced subsurface erosion, possibly tidal/lagoonal driven, to form voids that collapse.
- (3) Shock to the sedimentary sea floor caused by severe wave conditions associated with hurricanes (Stoddart, 1963).
- (4) Liquefaction of deep mud layers by seismic events such as blasting during oil exploration (Fig. 28) or earthquakes.
- (5) Dendritic relief patterns in the underlying Pleistocene limestone.

The slurry of muddy peat between the fallen blocks of peat at the inner limits of slumping, the undercut peat exposures, the partially decomposed sections of fine-fibered peat found in cores adjacent to slumping (Macintyre et al., 1995, this volume), the presence of escaping stained humic waters, and the dendritic slump patterns all suggest that fracturing and slumping are related to the decompositional erosion of older fine-fibered peat. This removal of the underlying fine-fibered peat probably involves processes of oxidation, gravity flow, and bottom current erosion (Hypotheses 1 and 2), which could be driven by hydrostatic forces related to the passage in the barrier reef 2 km directly eastward of Tobacco Range and to the atoll-like lagoon of Tobacco Range. These processes appear to concentrate initially along narrow fronts resulting in a poorly developed dendritic pattern (Figs. 2 and 3). In some cases, the older fine-fibered peat is removed some distance shoreward of the exposed peat walls, which results in isolated slump areas.

Stoddart's (1963) observations on the atoll-like Turniffe mangrove system following the impact of Hurricane Hattie suggest the hypothesis (No. 3) that catastrophic hydrostatic forces could be responsible for initiating the fracturing and slumping in the Tobacco Range system where the consolidated coarse-fibered peat deposits are underlain by thick deposits of easily erodable fine-fibered layers and thin slippery basal muds.

Hypothesis 4 is not likely, although seismic blasting tracks are clearly visible adjacent to the northeastern portion of the fracture zone (see Fig. 28). Blasting from petroleum exploration ships has occurred next to the peat beds of many of the Belizean mangrove islands, such as nearby Twin Cays (Fig. 1), and no comparable slumping has occurred. Also, the weathered seaward central slump depressions greatly predate seismic testing. It should be kept in mind, however, that natural

seismic events (earthquakes) have occurred and continue to be reported in this area and may have played a role in the initiation of slumping processes off Tobacco Range.

It is conceivable that dendritic relief on the underlying Pleistocene limestone surface, possibly old spur and groove deposits (Hypothesis 5), might have had some control of these slump patterns. This, however, could only be confirmed by detailed seismic studies.

It is not possible to determine how or when the fracturing and slumping started in this area. The very subdued relief of the peat blocks in the broad depressions at the outer limits of slumping (Fig. 29), and the complete colonization by the slow growing seagrass, *Thalassia testudinum*, indicates that collapsing of submerged peat has been occurring for a long period of time -- centuries or possibly millennia. We do know that the process is ongoing since we have noted the formation of new cracks and fissures (Fig. 6) and observed slumping (Fig. 10) during the present study. The isolated slump areas eventually connect to the main areas, forming additional branches of the dendritic pattern. With time, most of the peat deposits between the dendritic branches will collapse forming broader slump depressions.

ACKNOWLEDGEMENTS

This study was funded by the Caribbean Coral Reef Ecosystems Program (CCRE Contribution Number 451) and the Smithsonian Marine Station at Link Port (SMSLP Contribution Number 378).

REFERENCES

- Folk, R.L. 1961. Petrology of Sedimentary Rocks. Hemphill's, Austin, Texas. 154 pp.
- Littler, D.S., M.M. Littler and B.L. Brooks. 1995. Marine Algae and Seagrasses from the Tobacco Range Fracture Zone, Belize, C.A. *Atoll Research Bulletin*, 429: 1-43.
- Littler, D.S., M.M. Littler, K.E. Bucher, and J.N. Norris 1989. Marine Plants of the Caribbean, a Field Guide from Florida to Brazil, Smithsonian Institution Press. 272 pp.
- Macintyre, I.G., M.M. Littler, and D.S. Littler. 1995. Holocene History of Tobacco Range, Belize, Central America. *Atoll Research Bulletin*, 430: 1-18.

- Stoddart, D.R. 1963. Effects of Hurricane Hattie on the British Honduras Reefs and Cays, October 30-31, 1961. *Atoll Research Bulletin*, 95: 1-142.
- Thornbury, W.D. 1954. Principles of Geomorphology. John Wiley and Sons, N.Y. 618 pp.
- Tsuda, R.T., and I.A. Abbott. 1985. Collection, Handling, Preservation, and Logistics. Pages 67-86 *In* M.M. Littler and D.S. Littler, eds. Handbook of Phycological Methods. Ecological Field Methods: Macroalgae. Cambridge Univ. Press, Cambridge.

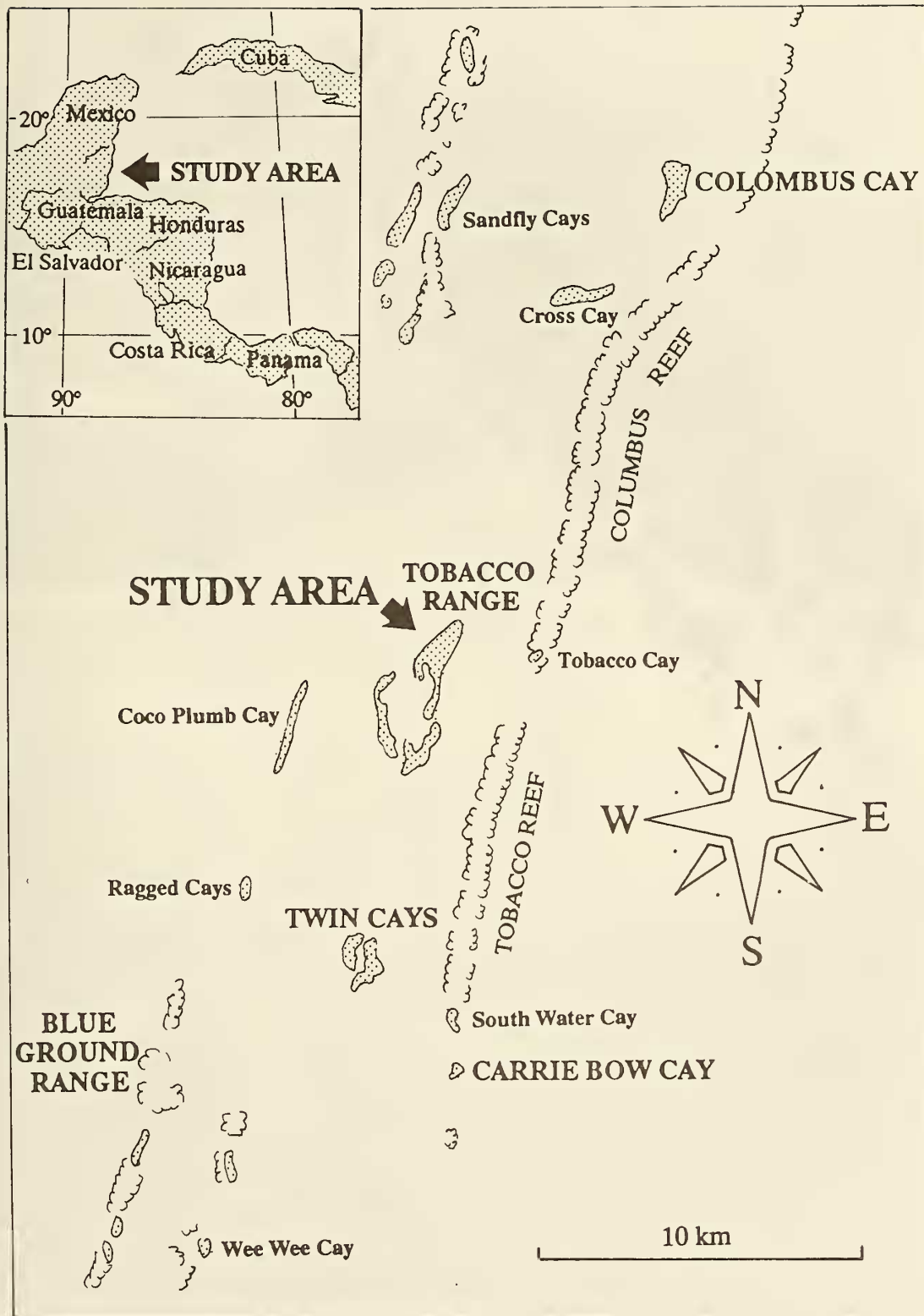


Figure 1. Map of Central Province of the Belize Barrier Reef showing location of Tobacco Range mangrove system and study area.

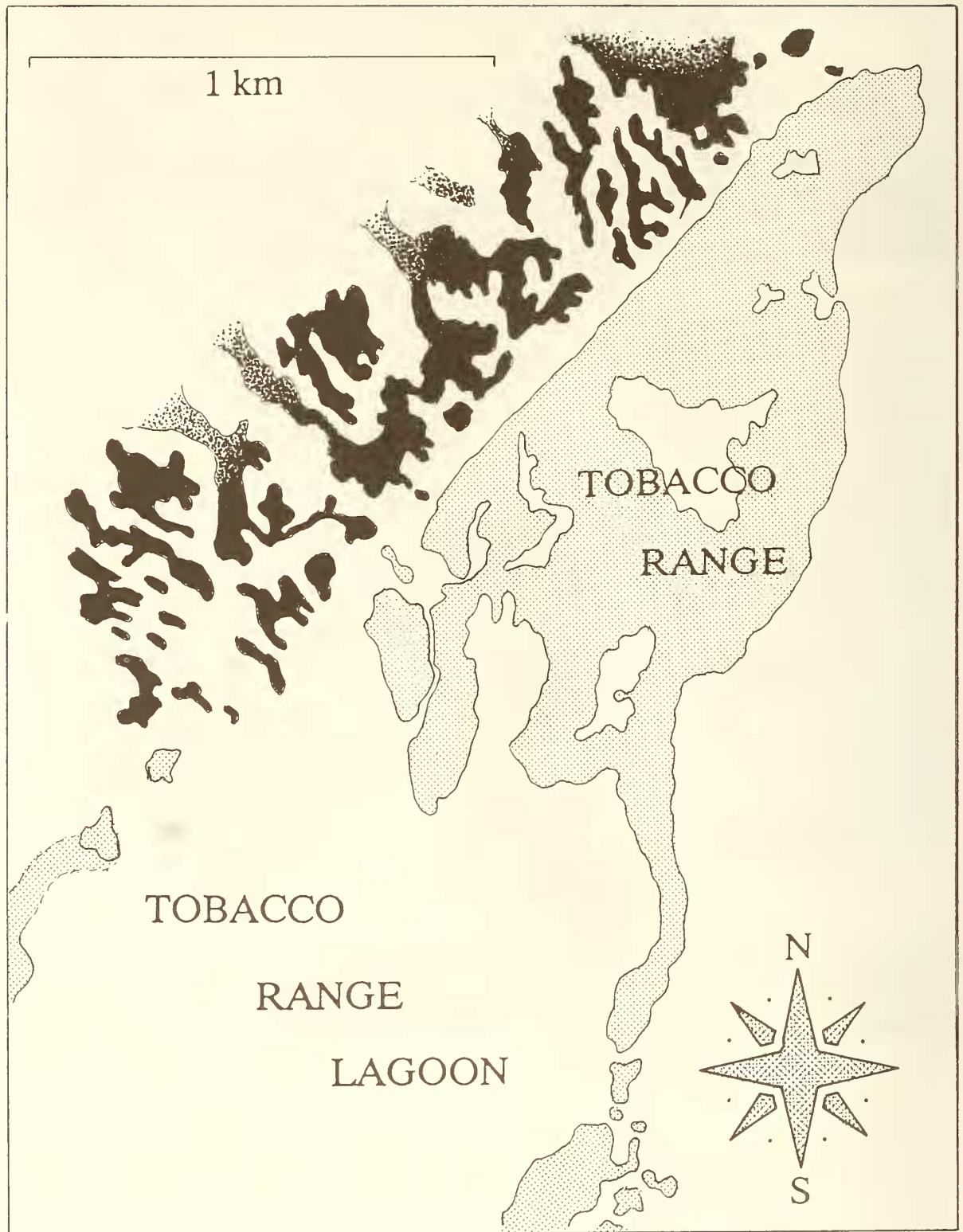


Figure 2. Detailed map showing the Tobacco Range Fracture Zone off the northeastern island (black shading, based on aerial photography).



Figure 3. Oblique aerial photograph, looking northward at the northeastern island of Tobacco Range, showing the dendritic slump areas (dark) of the fracture zone.

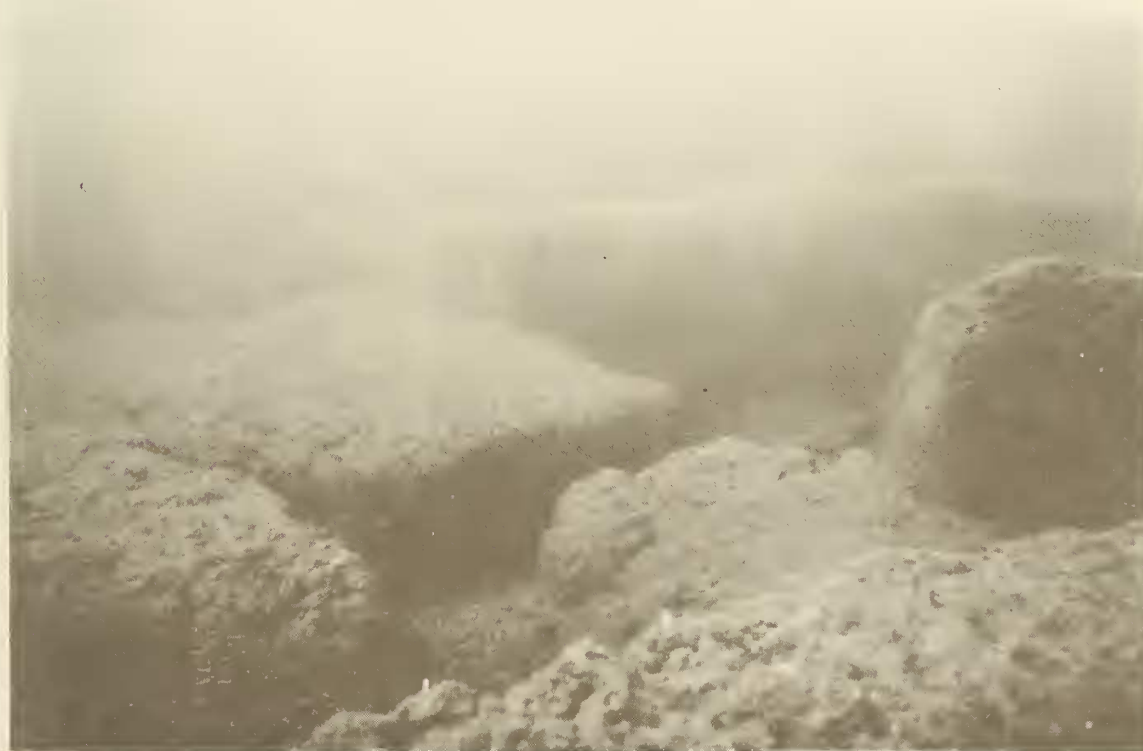


Figure 4. Underwater photograph of slumped peat blocks.



Figure 5. *Thalassia testudinum* - dominated community in nearshore unfractured area.



Figure 6. Initial crack prior to incipient fracturing and slumping.



Figure 7. Exposed wall of fossilized peat on fracture margin.



Figure 8. Array of slumped peat blocks.

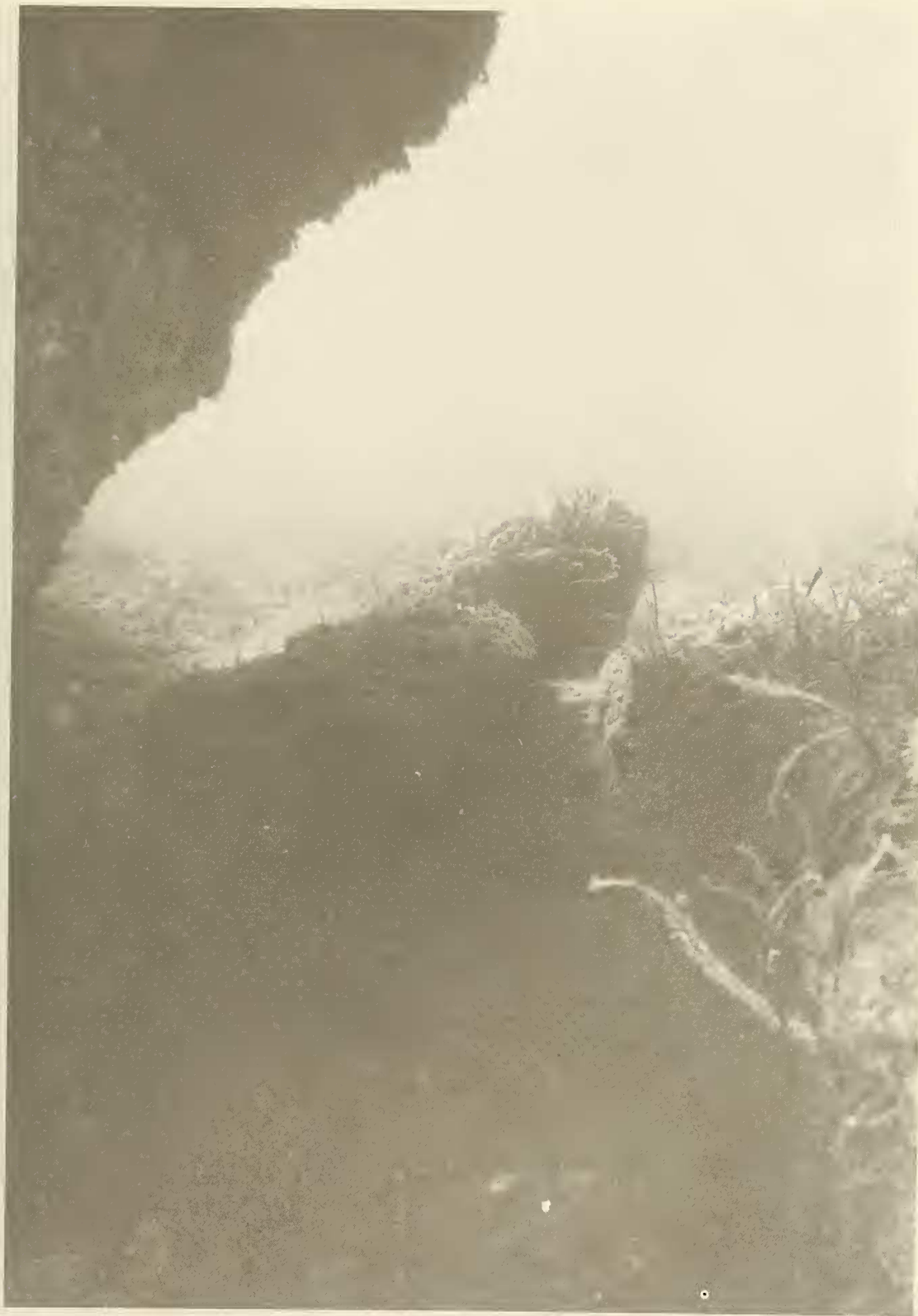


Figure 9. Peat block partially sunken into slurry of peat mud.



Figure 10. Peat fragment in the process of slumping.



Figure 11 A & B. Tilted peat blocks showing sparse *Thalassia testudinum* community on upper surfaces.



Figure 12. Chaotic jumble of peat blocks.



Figure 13. Stratified pattern of depositional zonation.



Figure 14. Platform and undercut features of peat deposits.

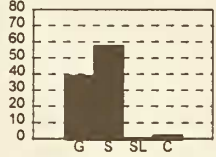
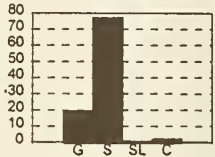

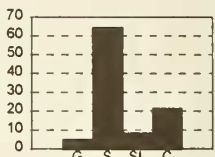
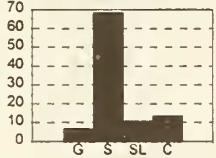
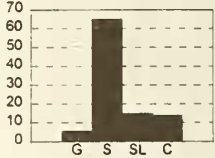
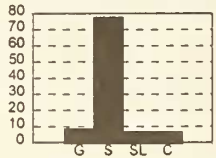
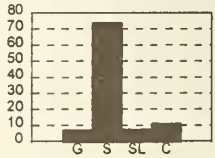

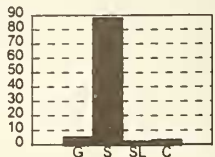
Seafloor Characteristics	Transect that follows and extends core study transect (Fig. 2, Macintyre et al., 1995, this volume)	Parallel transect 100m southwest of core study transect
Shallow unfractured peat surface adjacent to shoreline. Depth 3m	<p>Poorly sorted sandy gravel. Dominantly molluscs with some benthic foraminifera, <u>Halimeda</u> and echinoids.</p> 	<p>Poorly sorted gravelly sand. Molluscs, benthic foraminifera and <u>Halimeda</u>. Some echinoid and peat fragments.</p> 
Sediment from between the most recently collapsed peat blocks at inner limit of slumping. Depth 6m	<p>Very poorly sorted gravelly muddy sand. Mostly peat. Scattered grains of molluscs, benthic foraminifera, echinoids and <u>Halimeda</u>.</p> 	<p>Very poorly sorted gravelly muddy sand. Mostly peat. Traces of <u>Halimeda</u>, molluscs, and benthic foraminifera.</p> 
Area of low relief slumping located seaward of active slumping sites. Depth 6m	<p>Very poorly sorted gravelly muddy sand. Molluscs, benthic foraminifera and peat. Some echinoids and <u>Halimeda</u>.</p> 	<p>Very poorly sorted gravelly muddy sand. Peat with molluscs, benthic foraminifera, and some echinoids.</p> 
	<p>Very poorly sorted gravelly muddy sand. Molluscs and <u>Halimeda</u>. Some peat, benthic foraminifera, and echinoids.</p> 	<p>Very poorly sorted gravelly muddy sand. Molluscs, benthic foraminifera, <u>Halimeda</u> and echinoids. Abundant peat.</p> 
<u>Thalassia</u> covered seafloor beyond fracture and slump zone. About 300m from shore. Depth 6m	<p>Very poorly sorted, slightly gravelly muddy sand. Molluscs and benthic foraminifera with some <u>Halimeda</u>, echinoids and peat.</p> 	<p>Very poorly sorted gravelly sand. Molluscs and benthic foraminifera with some <u>Halimeda</u>, echinoids and peat.</p> 

Figure 15. Characteristics of surface sediment samples from transects across the central region of the fracture zone. Size-distribution histograms have a vertical percentage scale and horizontal size scale (G - gravel, >2mm; S - sand, 2 mm-63 μ m; SL - silt, 63-4 μ m; C - clay, <4 μ m).

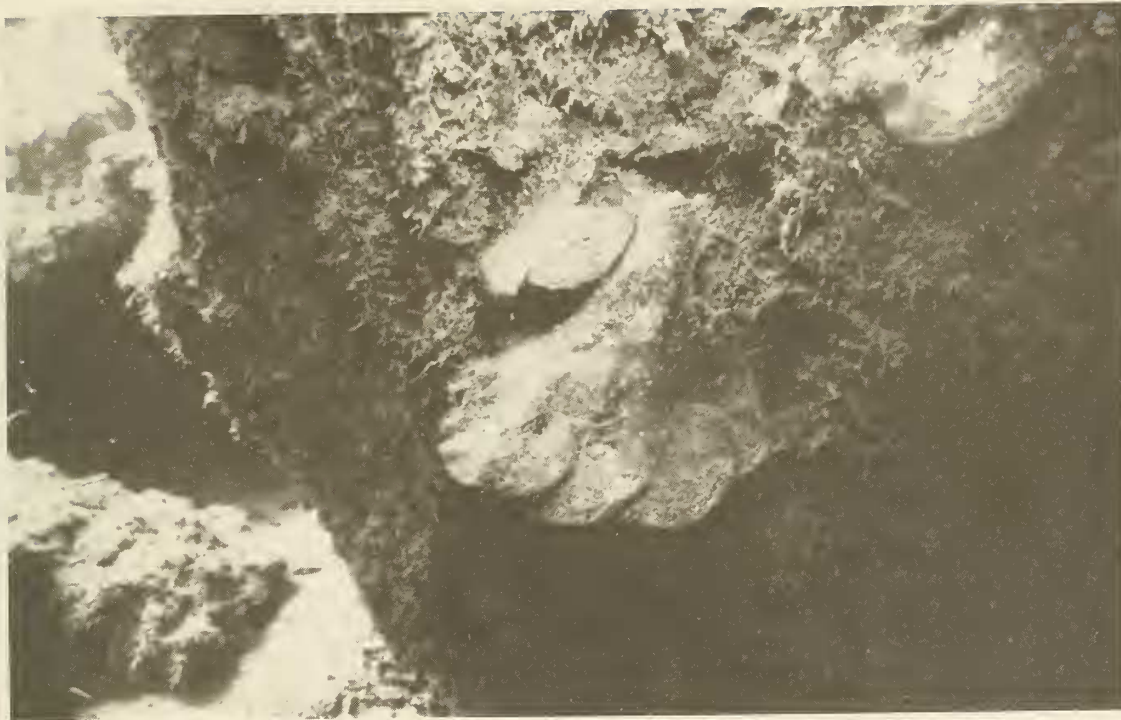


Figure 16. Population of *Lobophora variegata* (shelf form) on vertical fractured peat wall.



Figure 17. Characteristic rhizophytic algae rooted in soft bottoms of fractured depressions.



Figure 18. Population of *Halophila decipiens* characteristic of sedimentary bottoms within fractures.



Figure 19. Drift blades of *Thalassia testudinum* accumulating in fracture depressions.



Figure 20. The yellow sponge *Mycale laevis* conspicuous on fracture walls.



Figure 21. The burgundy sponge *Mycale laxissima* common within fractures.



Figure 22. The orange tunicate *Ecteinascidia turbinata* common within the fracture zone, but otherwise rare in nearby mangrove and reefal habitats.



Figure 23. Medusa of *Casiopea xanachuna* abundant on the muddy peat bottoms of fractures.



Figure 24 A & B. Burial of the southern stingray *Dasyatis americana* (A) causes considerable bioturbation (B) of the soft sediments.



Figure 25 A & B. "Interior halos" created by trapped living gastropods (A), which ultimately die leaving behind grooved tracks of bioturbation (B).

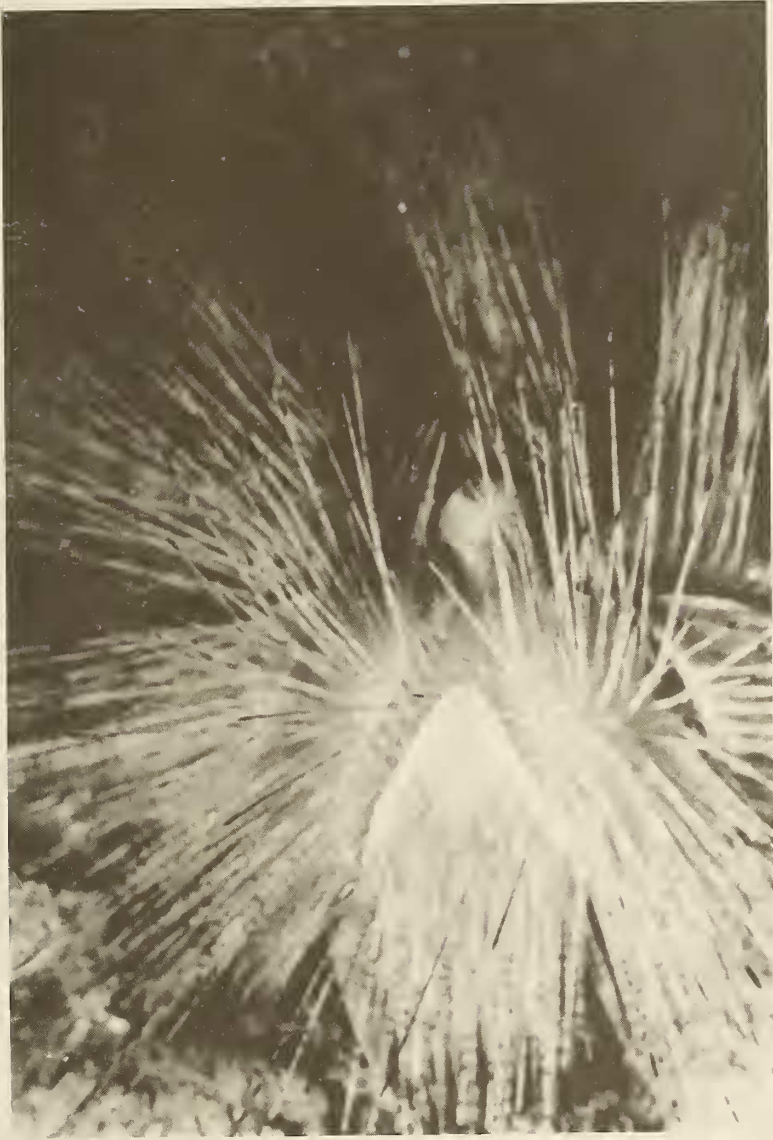


Figure 26. The deep sea urchin *Astropyga magnifica* (new record for Belize) from one of the southwestern fractures.



Figure 27. The long-spined urchin *Diadema antillarum* commonly found in the fracture zone and elsewhere.



Figure 28. Aerial view of seismic blast sites (straight line of white sand patches in lower left) from petroleum exploration in vicinity of Tobacco Range.



Figure 29. Subdued relief of slumped peat at the outer limits of the fracture zone. All eroded surfaces have been recolonized by the *Thalassia testudinum* community.